# NUCLEAR PHYSICS

## 1. NUCLEUS

(i) Central core of every atom.

(ii) Discovered by Rutherford in $\alpha$-scattering experiment.

(iii) The order of nuclear size = $10^{-15}$ m or fm while the order of atomic size = $10^{-10}$ m or Å

(iv) Protons and neutrons, together referred as nucleons.

(v) A nuclide is represented by ${}_{Z}^{A}X$

Z = atomic number = p (no. of protons)

A = mass number = total no. of nucleons = n + p

(vi) Atomic masses are generally represented by atomic mass unit (u)

$$1u = \frac{\text{mass of } C^{12} \text{ atom}}{12} = 1.66 \times 10^{-27} \text{ kg}$$

$m_p = 1.6726 \times 10^{-27}$ kg = 1.00727 u

$m_n = 1.6749 \times 10^{-27}$ kg = 1.00866 u

$m_e = 9.1 \times 10^{-31}$ kg = 0.00055 u

### 1.1 Types of Nuclei

(i) Isotope : same Z

(ii) Isobar : same A

(iii) Isotone : same (A – Z)

### 1.2 Properties of Nuclei

**Size of Nucleus :** (Order is fermi)

As the number of nucleons in nucleus increases its size also increases and relation between its radius and mass number is $R \propto A^{1/3}$

$$R = R_0 A^{1/3}$$

Here $R_0$ is a constant and its value $R_0 \approx 1.2$ fm.

**Volume of Nucleus**

Volume $\propto R^3$ (But $R \propto A^{1/3}$) or volume $\propto A$

**Mass of Nucleus**

Its mass is quite small compare to gm or kg. Therefore it is measured in another unit - amu (Atomic Mass Unit)

Mass of an nucleus of mass number A is $\simeq Am_p \simeq A$ amu or mass of an nucleus, $m \propto A$

**Density of Nucleus ($\rho$)**

$$\rho = \frac{\text{mass}}{\text{volume}} \cong \frac{Am_p}{\frac{4}{3}\pi R^3} = \frac{Am_p}{\frac{4}{3}\pi R_0^{\,3} A} = \frac{3m_p}{4\pi R_0^{\,3}} \simeq 3 \times 10^{17} \text{kg/m}^3$$

It means $\rho$ is independent of A. Density of nuclei of all types of element is same and its order is $10^{17}$ kg/m$^3$ or $10^{14}$ gm/cm$^3$

## Illustrations

**Illustration 1.**

Calculate mass no. of that nucleus whose radius is half of $Ge^{72}$.

**Solution.**

$r \propto A^{1/3}$

$$\frac{r/2}{r} = \left(\frac{A}{72}\right)^{1/3} \Rightarrow \frac{1}{8} = \frac{A}{72} \quad \Rightarrow A = 9$$

**Illustration 2.**

Find the density of ${}^{12}_{6}C$

**Solution.**

Mass of nucleus $\approx 12m_p = 12 \times 1.66 \times 10^{-27}$ kg  $\{m_p$ = mass of proton$\}$

$$\rho = \frac{M}{\frac{4}{3}\pi R^3} = \frac{12 \times 1.66 \times 10^{-27}\,\text{kg}}{\frac{4}{3}\pi[1.2 \times 10^{-15}(12)^{1/3}]^3\ \text{m}^3} = 2.4 \times 10^{17}\ \text{kg m}^{-3}$$

## 1.3 Forces acting inside the nucleus

There are three forces interacting between nucleons, these are

(i) Gravitational force - weakest force of nature

(ii) Electrostatic repulsive (coulombian) force $\rightarrow$ only works between proton proton. This is stronger than gravitational force.

(iii) Nuclear force $\rightarrow$ strongest intraction that holds nucleons together to form nuclei and it is powerful enough to overcome the electric repulsion of proton and proton.

## 1.4 Features of Nuclear Force ($F_n$) :–

1. The strongest force in the universe.
2. Works only between the nucleons.
3. **Very short range :** only upto size of nucleus (3 or 4 fermi). More than this distance, nuclear force is almost zero.
4. **Very much depends upon distance :–** Small variation in distance may cause of large change in nuclear force while electrostatic force remains almost unaffected.
5. **Independent of charge :–** Interacts between n–n as well as between p–p and also between n–p.
6. **Spin dependent :–** It is stronger between nucleons having same sense of spin than between nucleons having opposite sense of spin.
7. **It is not a central force :–** Definition of central force ($F_c$) : Whose line of action always passes through a fixed point and its magnitude depends only on distance, if medium is same.

$$\vec{F}_c = \frac{K}{r^n}(\pm\ \hat{r}) \text{ is central force.}$$

Electrostatic and gravitational forces are central forces.

8. **Nature :–** **(i) Attractive –** If distance is greater than 0.8 fm or above. **(ii) Repulsive –** If distance is lesser than 0.8 fm.

## 2. EINSTEIN'S MASS ENERGY EQUIVALENCE

According to Einstein, mass can be converted into energy and energy into mass. This relation is given by -

$$E = mc^2$$

Here $E$ = total energy associated with mass m ; $c^2$ = used as a conversion coefficient

### 2.1 Mass defect

(i) Mass of a nucleus is always less than the sum of masses of its constituent nucleons. This difference is called mass defect.

(ii) If observed mass of nucleus $_ZX^A$ be M, mass of proton is $M_p$ and mass of neutron is $M_n$ then

mass defect = $\Delta m = [ZM_p + (A - Z)M_n] - M$.

(iii) If M is taken as mass atom of $_ZX^A$ instead of mass of nucleus then

$$\Delta m = [Z(M_p + M_e) + (A - Z)M_n] - M_{atom}$$

### 2.2 Binding energy ($E_b$)

(i) Binding energy of a nucleus is the energy required to split it into its nucleons (free).

(ii) $\Delta E_b = \Delta m.c^2$

(iii) It is always positive and numerically equal to the energy equivalent of mass defect (or equal to the energy liberated when it was formed)

### 2.3 Binding Energy per Nucleon $\left[\frac{\Delta E_b}{A}\right]$

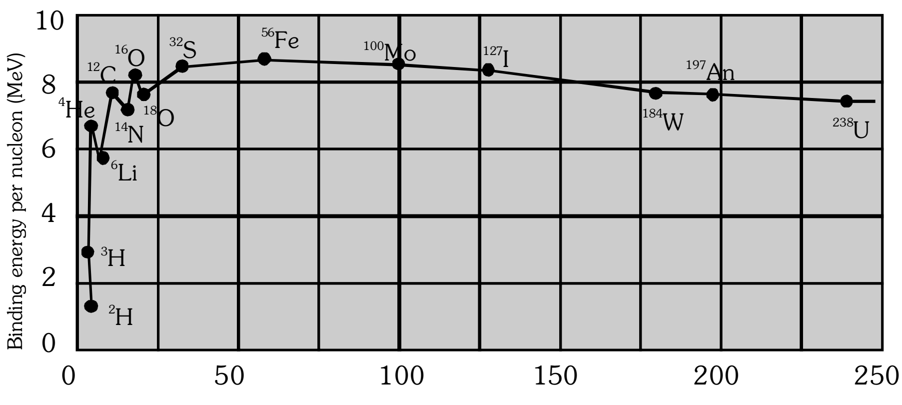



**FIGURE :** The binding energy per nucleon as a function of mass number.

(i) The value of binding energy per nucleon decides the stability of a nucleus. It is obtained by dividing binding energy by the mass number of given nucleus.

(ii) The following figure shows the binding energy per nucleon plotted against the mass number of various atoms nuclei

Greater the binding energy per nucleon, the more stable the nucleus.

(iii) It is maximum for isotope of iron – $^{56}_{26}Fe$ and is 8.8 MeV/nucleon. It is the most stable nucleus.

(iv) For Uranium, binding energy per nucleon is about 7.7 MeV/nucleon and it is unstable.

(v) The medium size nuclei are more stable than light or heavy nuclei.

## 3. NUCLEAR FISSION

Splitting of a heavy nucleus (A > 230) into two or more lighter nuclei when struck by a neutron.

In this process certain mass disapears which is obtained in the form of energy (enormous amount)

$A + n \rightarrow$ excited nucleus $\rightarrow B + C + Q$

Hahn and Strassmann done the first fission (fission of nucleus of $U^{235}$).

When $U^{235}$ is bombarded by a neutron it splits into two fragments and 2 or 3 secondary neutrons and releases about 200 MeV energy per fission (or from single nucleus)

Fragments are uncertain but each time energy released is almost same.

Possible reactions are -

$$U^{235} + {}_0n^1 \rightarrow Ba + Kr + 3\,{}_0n^1 + 200\text{ MeV}$$

or $$U^{235} + {}_0n^1 \rightarrow Xe + Sr + 2\,{}_0n^1 + 200\text{ MeV}$$

and many other reactions are possible.

(i) The average number of secondary neutrons is 2.5.

(ii) Nuclear fission can be explained by using " liquid drop model" also.

(iii) The mass defect $\Delta m$ is about 0.1% of mass of fissioned nucleus

(iv) About 93% of released energy (Q) is appear in the form of kinetic energies of products and about 7% part in the form of $\gamma$ - rays.

## 4. NUCLEAR CHAIN REACTION

The equation of fission of $U^{235}$ is $\quad {}_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{144} + {}_{36}Kr^{89} + 3\,{}_0n^1 + Q$

These three secondary neutrons produced in the reaction may cause of fission of three more $U^{235}$ and give 9 neutrons, which in turn, may cause of nine more fission of $U^{235}$ and so on.

Thus a continuous 'Nuclear Chain reacion' would start.

If there is no control on chain reaction then in a short time ($\simeq 10^{-6}$ sec.) a huge amount of energy will be released. (This is the principle of 'Atom bomb')

If chain reaction is controlled then produced energy can be used for peaceful purposes. For example nuclear reactor (Based on fission) generats electricity.

### 4.1 Natural Uranium

It is mixture of $U^{235}$ (0.7%) and $U^{238}$ (99.3%)

$U^{235}$ is easily fissionable, by slow neutron (or thermal neutrons) having K.E. of the order of 0.03 eV.

To improve the quality, percentage of $U^{235}$ is increased to 3%. The improved uranium is called 'Enriched Uranium' (97% $U^{238}$ and 3% $U^{235}$)

### 4.2 Losses of Secondary Neutrons

**Leakage of neutrons from the system**

Due to their high K.E. some neutrons escape from the system.

**Absorption of neutrons by $U^{238}$**

$U^{238}$ is not fissionable by these secondary fast neutrons. But $U^{238}$ absorbs some fast neutrons.

### 4.3 Critical Size (or mass)

In order to sustain chain reaction in a sample of enriched uranium, it is required that the number of lost neutrons should be much smaller than the number of neutrons produced in a fission process. For it the size of uranium block should be equal or greater than a certain size called **critical size**.

### 4.4 Reproduction factor $(K) = \dfrac{\text{rate of production of neutrons}}{\text{rate of loss of neutrons}}$

(i) If size of Uranium used is 'Critical' then K = 1 and the chain reaction will be steady or sustained (As in nuclear reaction)

(ii) If size of Uranium used is 'Super critical' then K > 1 and chain reaction will accelerate resulting in a explosion (As in atom bomb)

(iii) If size of Uranium used is 'Sub Critical' then K < 1 and chain reaction will retard and ultimately stop.

## 5. NUCLEAR REACTOR (K = 1)

Its main constituents are -

### 5.1 Nuclear Fuel : Commonly used are $U^{235}$ , $Pu^{239}$ .

$Pu^{239}$ is the best.

But $Pu^{239}$ is not naturally available and $U^{235}$ is used in most of the reactors.

### 5.2 Moderator

Its function is to slow down the fast secondary neutrons. Because only slow neutrons are capable for the fission of $U^{235}$. The moderator should be light and it should not absorb neutrons. Commonly, Heavy water ($D_2O$, molecular weight 20 gm.) are used.

### 5.3 Control rods

They have the ability to capture the slow neutrons and can control the rate of chain reaction at any stage.

Boron and Cadmium are best absorber of neutrons.

### 5.4 Coolant

A substance which absorb the produced heat and transfers it to water for further use. Generaly coolant is water at high pressure

## 6. FAST BREADER REACTORS

The atomic reactor in which fresh fissionable fuel ($Pu^{239}$) is produced along with energy.

**Fuel :** Natural Uranium.

During fission of $U^{235}$, energy and secondary neutrons are produced. These secondary neutrons are absorbed by $U^{238}$ and $U^{239}$ is formed. This $U^{239}$ converts into $Pu^{239}$ after two beta decay. This $Pu^{239}$ can be separated, its half life is 2400 years.

$${}_{92}U^{238} + {}_{0}n^{1} \rightarrow {}_{92}U^{239} \xrightarrow{2\beta^-} {}_{94}Pu^{239} \text{ (best fuel of fission)}$$

This $Pu^{239}$ can be used in nuclear weapons because of its small critical size than $U^{235}$.

## 7. NUCLEAR FUSION

It is the phenomenon of fusing two or more lighter nuclei to form a single heavy nucleus.

$A + B \rightarrow C + Q$ (Fusion)

The product (C) is more stable then reactants (A and B).

and $m_c < (m_a + m_b)$

and mass defect $\Delta m = [(m_a + m_b) - m_c]$ amu

Energy released is $E = \Delta m \times 931$ MeV/amu

The total binding energy and binding energy per nucleon C both are more than of A and B.

$$\Delta E = E_c - (E_a + E_b)$$

Fusion of four hydrogen nuclei into helium nucleus -

$$4({}_1H^1) \rightarrow {}_2He^4 + 2\ {}_+\beta^0 + 2\ \nu + 26\ \text{MeV}$$

(i) Energy released per fission >> Energy released per fusion

(ii) Energy per nucleon in fission $\left[= \frac{200}{235} \simeq 0.85\text{MeV}\right]$ << energy per nucleon in fusion $\left[= \frac{26}{4} \simeq 6.5\text{MeV}\right]$

## 7.1 Required condition for nuclear fusion

**(a) High Temperature**

Which provide kinetic energy to nuclei to overcome the repulsive electrostatic force between them.

**(b) High Pressure (or density)**

Which ensure frequent collision and increases the probability of fusion.

These condition exist in the sun and in many other stars. The source of energy in the sun is nuclear fusion, where hydrogen is in plasma state and protons fuse to form helium nuclei.

# 8. PAIR PRODUCTION AND PAIR ANNIHILATION

| PAIR PRODUCTION | PAIR ANNIHILATION |
|---|---|
| A $\gamma$-photon of energy more than $\geq$ 1.02 MeV, when interact with a nucleus produces pair of electron ($e^-$) and positron ($e^+$).<br>The energy equivalent to rest mass of $e^-$ (or $e^+$)=0.51 MeV.<br>The energy equivalent to rest mass of pair ($e^- + e^+$) = 1.02 MeV.<br><br>For pair production Energy of photon 1.02 MeV.<br>If energy of photon is more than 1.02 MeV, the extra energy (E - 1.02) MeV devides approximately in equal amount to each particle as the kinetic<br>energy. $(K.E.)_{e^- \text{ or } e^+} = \left[\frac{E_{Ph} - 1.02}{2}\right]$ MeV<br><br>If E < 1.02 MeV, pair will not produce. | When electron and positron combines they annihilates to each other and only energy is released in the form of two gama photons. |

## GOLDEN KEY POINTS

- The density of nuclear matter is independent of the size of the nucleus. The mass density of the atom does not follow this rule.
- The radius of a nucleus determined by electron scattering is found to be slightly different from that determined by alpha-particle scattering. This is because electron scattering senses the charge distribution of the nucleus, whereas alpha and similar particles sense the nuclear matter.
- The nature of the binding energy (per nucleon) curve shows that exothermic nuclear reactions are possible, when two light nuclei fuse or when a heavy nucleus undergoes fission into nuclei with intermediate mass.
- For fusion, the light nuclei must have sufficient initial energy to overcome the coulomb potential barrier. That is why fusion requires very high temperatures.
- Although the binding energy (per nucleon) curve is smooth and slowly varying, it shows peaks at nuclides like $^4He$, $^{16}O$ etc. This is considered as evidence of atom-like shell structure in nuclei.
- A free neutron is unstable ($n \to p + e^- + \bar{\nu}$). But a similar free proton decay is not possible, since a proton is (slightly) lighter than a neutron.
- Gamma emission usually follows alpha or beta emission. A nucleus in an excited (higher) state goes to a lower state by emitting a gamma photon. A nucleus may be left in an excited state after alpha or beta emission. Successive emission of gamma rays from the same nucleus is a clear proof that nuclei also have discrete energy levels as do the atoms.
- Hydrogen bomb is based on fusion.

## Illustrations

**Illustration 3.**

The mass defect in a nuclear fusion reaction is 0.05%. What amount of energy will be liberated in one kg fusion reaction ?

**Solution.**

Mass defect = $\Delta m$ = 0.05% of 1 kg = $\frac{0.05}{100}$ kg = $5 \times 10^{-4}$ kg

Energy liberated = $(\Delta m)c^2 = (5 \times 10^{-4})\,(9 \times 10^{16})\text{J} = 45 \times 10^{12}$ J

**Illustration 4.**

What is energy released by fission of 1 gm $U^{235}$ ?

**Solution.**

Number of atom in 1 gm of $U^{235} = \frac{N_A}{235}$

$$\text{Energy released} = \frac{N_A}{235} \times 200 \text{ MeV} = \frac{6.023 \times 10^{23}}{235} \times 200 \text{ MeV} = 5 \times 10^{23} \text{ MeV}$$

$$= (5 \times 10^{23})\,(1.6 \times 10^{-13} \text{ J}) = 8 \times 10^{10} \text{ J}$$

$$= \frac{8 \times 10^{10}}{3.6 \times 10^{6}} \text{ kWH} = 2.22 \times 10^{4} \text{ kWH}$$

**Illustration 5.**

What is the power output of ${}^{235}_{92}U$ reactor if it takes 30 days to use up 2 kg of fuel and if each fission gives 185 MeV of usable energy ?

**Solution.**

Number of atoms in 2 kg of ${}^{235}_{92}U$ $= \dfrac{6.02\times10^{23}\times2\times10^{3}}{235} = 5.12\times10^{24}$

Therefore, energy released in 30 day $= 5.12\times10^{24}\times185\text{ MeV} = 1.51\times10^{14}\text{ J}$

$\therefore$ Energy released per second $= \dfrac{1\cdot51\times10^{14}}{30\times24\times60\times60} = 58.4\text{ MW}$

**Illustration 6.**

Obtain the binding energy of a nitrogen nucleus $\left({}^{14}_{7}N\right)$ in MeV from the following data.

$m_H = 1\cdot00783u,\ m_n = 1\cdot00867\ u,\ m_N = 14\cdot00307\ u$

**Solution.**

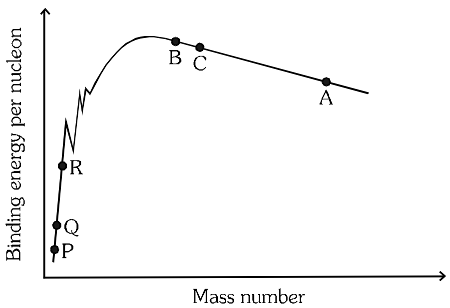
Mass defect $\Delta m = 7m_p + 7m_n - m_N = 7\times1\cdot00783 + 7\times1\cdot00867 - 14\cdot00307 = 0\cdot11243$ amu

Binding energy $= \Delta m\times931\text{ MeV} = 0\cdot11243\times931\text{ MeV} = 104\cdot67\text{ MeV}$

**Illustration 7.**

Explain nuclear fission & fusion on the basis of binding energy of nucleus. **[AIPMT 2004]**

**Solution.**




$\left.\begin{array}{l}\text{In fission : nucleus A breaks into B \& C}\\ \text{In fussion : P \& Q fuse to result in nucleus R}\end{array}\right\}$

In both cases the net B.E. increases resulting in energy release.

**Illustration 8.**

Show that the nucleus ${}^{238}_{92}U$ emitting a proton through the decay process ${}^{238}_{92}U \rightarrow {}^{237}_{91}Pa + {}^{1}_{1}H$ can not proceed spontaneously . **[AIPMT 2006]**

Mass of uranium = 238.05079 a.m.u.

Mass of paladium = 237.05121 a.m.u.

Mass of proton = 1.00783 a.m.u.

**Solution.**

Here $Q = (238.05079 - 237.05121 - 1.00783)c^2 = (-0.00825u)c^2$

As the Q for this process is negative, the decay can not proceed spontaneously

**Illustration 9.**

Write three characteristic features which distinguish nuclear force from coulomb force. **[AIPMT 2007]**

**Solution.**

| **Nuclear force** | **Coulomb force** (Write any three) |
|---|---|
| (i) Short range | Long range |
| (ii) Not a central force | Central force |
| (iii) Spin dependent | Spin independent |
| (iv) Charge independent | Charge dependent |
| (v) Strong force | Comparitively weak force |

**Illustration 10.**

The radionuclide ${}^{11}_{6}C$ dacays by $\beta^{+}$ emission. Write symbolically this decay process.

Given that $m({}^{11}_{6}C) = 11.011434$ u **[AIPMT 2008]**

$m({}^{11}_{6}B) = 11.009305$ u

$m_e = 0.000548$ u, $1u = 931.5$ MeV/$c^2$

Calculate the Q-value.

**Solution.**

Equation of $\beta^{+}$-decay of ${}_6C^{11}$ ; ${}_6C^{11} \longrightarrow {}_5B^{11} + {}_{+1}\beta^0 + \nu + Q$

Q-value of reaction = $\Delta mc^2$

$$= \left[m\left({}_6C^{11}\right) - 6m_e - m\left({}_5B^{11}\right) + 5m_e - m_e\right]c^2 = \left[m\left({}_6C^{11}\right) - m\left({}_5B^{11}\right) - 2m_e\right]c^2$$

$$= [11.011434 - 11.009305 - 2 \times 0.000548]uc^2$$

$$= [0.001033]\ uc^2 = 0.001033 \times 931.5\ \text{MeV} = 0.962\ \text{MeV}$$

**Illustration 11.**

Calculate the percent increase in mass of an electron accelerated by a potential difference of 500 kV.

**[AIPMT 2004]**

**Solution.**

Kinetic energy of electron = 500 keV & Rest mass energy of electron = 511 keV

Total energy = $mc^2 = m_0c^2 + KE = (511 + 500)$ keV

Percent increase in mass $= \dfrac{m - m_0}{m_0} \times 100 = \dfrac{500}{511} \times 100 = 97.8\ \%$

## BEGINNER'S BOX-1

**1.** The Q value of a nuclear reaction A + b → C + d is defined by

$Q = [\, m_A + m_b - m_C - m_d]c^2$

where the masses refer to the respective nuclei. Determine from the given data the Q-value of the following reactions and state whether the reactions are exothermic or endothermic.

(i) ${}_1^1H + {}_1^3H \rightarrow {}_1^2H + {}_1^2H$

(ii) ${}_6^{12}C + {}_6^{12}C \rightarrow {}_{10}^{20}Ne + {}_2^4He$

Atomic masses are given to be

m (${}_1^1H$) = 1.007825 u

m (${}_1^2H$) = 2.014102 u

m (${}_1^3H$) = 3.016049 u

m (${}_6^{12}C$) = 12.000000 u

m (${}_{10}^{20}Ne$) = 19.992439 u

mass of He atom is 4.0015 amu

**2.** Calculate the binding energy of ${}_{17}Cl^{35}$ if mass of ${}_{17}Cl^{35}$ nucleus is 34.98 amu, mass of neutron is 1.008665 amu and mass of proton is 1.007277 amu.

**3.** Calculate the energy released by the fission of 2 g of ${}_{92}U^{235}$ in kWh. Given that the energy released per fission is 200 MeV.

**4.** If the energy released in the fission of one nucleus is $3{\cdot}2 \times 10^{-11}$J, then find number of nuclei required per second in a power plant of 16 kW.

**5.** Find out the mass of Uranium required per day to generate 10 MW power from the fission of ${}_{92}U^{235}$.

**6.** The mass defect in a nuclear fusion reaction is 0.3 percent. What amount of energy will be liberated in one kg fusion reaction ?

**7.** Two nuclei have their mass numbers in ratio 1 : 3. What is the ratio of nuclear densities ?**[AIPMT 2006]**

# RADIOACTIVITY

## 1. RADIOACTIVITY :

(i) Spontaneous emission of radiations from the nucleus is known as **radioactivity** and substances showing this property are called **radioactive substances**.

(ii) Only unstable nuclei exhibit this property.

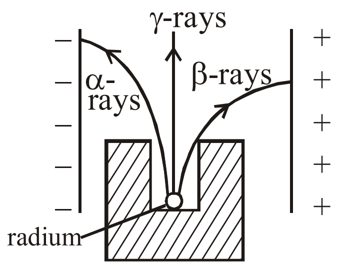
(iii) A particular nuclide (element) can radiate only a particular type of radiations at a time, according to its requirement of stability.

(iv) This phenomenon (Radioactivity) was discovered by ***Becquerel*** therefore the radioactive radiations are also called Becquerel radiations.

(v) Later on Curie couple (Merie Curie and Pierre Curie) discovered many other radioactive substances.

## 2. NATURE OF RADIOACTIVE RADIATIONS :

### 2.1 Rutherford's Experiment :–




Pb box (best absorber of nuclear radiations)

He put a sample of radioactive substance in a lead box and allow the emission of radiations through a small hole only. When the radiation enter into the external electric field, they split into three parts.

Radiations which deflect towards negative plate are called α–rays.

Radiations which deflect towards positive plate are called β–rays.

Radiations which are undeflected, called γ–rays.

(i) **Alpha rays :–** These are stream of positive charged particles i.e. particle nature.

(ii) **Beta rays :–** These are stream of negative charged particles i.e. particle nature.

(iii) **Gamma rays :–** These are electromagnetic waves.

### 2.2 Properties of α, β and γ rays :–

| | Features | α–particles | β–particles | γ–rays |
|---|---|---|---|---|
| 1. | Identity | Helium nucleus or doubly ionised helium ion ($_2He^4$) | Fast moving electrons ($_{-}\beta^0$ or $\beta^-$) | Electromagnetic wave (photons) |
| 2. | Charge | Twice of proton (+ 2e) | Electronic (– e) | Neutral |

| | | | | |
|---|---|---|---|---|
| 3. | Mass | $\approx 4m_p$, $m_p$–mass of proton | (rest mass of $\beta$) = (rest mass of ele.) | rest mass = 0 |
| 4. | Speed | $\approx 10^7$ m/s Their speed depends on nature of the nucleus. So, it is a characteristic speed. | $\approx 10^7$ m/s $\beta$-particles come out with different speeds from the same type of nucleus. therefore can not be a characteristic speed. | Only $c = 3 \times 10^8$ m/s $\gamma$-photons come out with same speed from all types of nucleus. So, can not be a characteristic speed. |
| 5. | K.E. | $\approx$ MeV | $\approx$ MeV | $\approx$ MeV |
| 6. | Energy spectrum | Line and discrete | Continuous | Line and discrete |
| 7. | Ionization power ($\alpha>\beta>\gamma$) | 10,000 times of $\gamma$-rays | 100 times of $\gamma$-rays (or $\frac{1}{100}$ times of $\alpha$) | 1 (or $\frac{1}{100}$ times of $\beta$) |
| 8. | Penetration power ($\gamma>\beta>\alpha$) | $\frac{1}{10000}$ times of $\gamma$-rays | $\frac{1}{100}$ times of $\gamma$-rays (100 times of $\alpha$) | 1 (100 times of $\beta$) |
| 9. | Effect of electric or magnetic field | Deflection | Deflection (More than $\alpha$) | No deflection |

## 3. TYPE OF RADIOACTIVE DECAY

### 3.1 $\alpha$–decay

In this decay, mass number decreases by 4 and atomic number decreases by 2. Its decay equation is

$$\underset{\text{(Parent)}}{{}^{A}_{Z}X} \longrightarrow \underset{\text{(Daughter)}}{{}^{A-4}_{Z-2}Y} + \underset{\text{Alpha}}{{}^{4}_{2}He}$$

In this decay total mass of product is less than the mass of parent. This difference in mass appears as kinetic energy of the products.

The disintegration energy or Q value for $\alpha$-decay.

$$Q = (m_X - m_Y - m_{He})c^2$$

### 3.2 $\beta$–decay

**(A)** The basic nuclear process underlying $\beta^-$-decay is the conversion of neutron to proton.

$$n \longrightarrow p + e^- + \bar{\nu}$$

(i) Its decay equation

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}\beta + \bar{\nu}$$

(ii) After $_{-}\beta^{\circ}$ decay, n/p ratio decreases.

(iii) $_{-}\beta^{\circ}$ always comes out from the nucleus along with antineutrino.

**(B)** The basic nuclear process underlying $\beta^+$-decay is the conversion of proton into neutron.

$$p \longrightarrow n + e^+ + \nu$$

(i) Its decay equation

$$_Z^AX \longrightarrow {}_{Z-1}^{\ \ A}Y + {}_{+1}^{\ o}\beta + \nu$$

(ii) After $_+\beta^o$ decay, n/p ratio increases.

(iii) $_+\beta^o$ comes out from the nucleus along with neutrino.

### 3.3 γ–decay :–

Similar to an atom, nucleus also have certain energy levels and nucleons occupy them. After α - decay (or β decay), daughter nucleus may be in excited state and return to ground state by emitting photons of high energy (MeV order) called γ - photons.

Equation of γ–decay :– $({}_ZX^A)^* \longrightarrow {}_ZX^A$ + γ - photons (or hν)

*Shows excited nucleus

(i) γ emission don't change the structure of nucleus

(ii) No change in Z and A

## GOLDEN KEY POINTS

- In β-decay either an electron or a positron is emitted by a nucleus, along with an antineutrino or a neutrino. The emitted particles share the available disintegration energy. The electrons and positrons emitted in β-decay have a continuous spectrum of energies from zero to a limit [$Q = (\Delta m)\, c^2$]
- Properties of neutrino & antineutrino
  - (i) Both are chargeless
  - (ii) Have almost zero rest mass (very light particles)
  - (iii) Have spin quantum number $\pm$ 1/2 and spin angular momentum $\pm$ h/2π similar to electron.
  - (iv) These are suggested by Pauli to explain the problems of energy conservation, linear momentum conservation, spin conservation and spin angular momentum conservation in β–decay.
- In β-decay parent & daughter are isobar.
- **The K-electron capture :** In K-capture a nucleus captures one of the inner orbital electrons and a proton transforms into a neutron. Hence K capture is like positron decay, in both n/p ratio increases. In this event a vacancy is created in K-shell to fill up the vacancy, electron transition takes place and X-rays are emitted.

$${}_ZX^A + {}_{-1}e^0\,(\text{K-capture}) \longrightarrow {}_{Z-1}Y^A + \text{X-rays} + \upsilon$$

## Illustrations

**Illustration 1.**

$${}_{90}Th^{234} \xrightarrow{\alpha} {}_aX^b \xrightarrow{{}_-\beta^0} {}_cY^d \xrightarrow{(p)} {}_{90}Th^{230}$$

Find a, b, c and d and identify particle p

**Solution.**

$${}_{90}Th^{234} \xrightarrow{\alpha} {}_{88}X^{230} \xrightarrow{{}_-\beta^0} {}_{89}Y^{230} \xrightarrow{P=({}_-\beta^0)} {}_{90}Th^{230}$$

**Illustration 2.**

$_{90}Th^{234} \xrightarrow{n\alpha\,,\,n'\,_{-}\beta^0} {_{83}Bi^{214}}$, Find n and n'

**Solution.**

Number of $\alpha$ particle, $n = N_\alpha = \dfrac{234-214}{4} = \dfrac{20}{4} = 5$

Number of $_{-}\beta$ particle, $n' = N_{-\beta} = Z_f - [Z_i - 2 \times \text{No. of } \alpha] = 83 - (90 - 2 \times 5) = 83 - 80 = 3$

## BEGINNER'S BOX-2

1. $_{92}U^{238} \xrightarrow{\alpha} \xrightarrow{_{+}\beta^0} {_aX^b}$, find a & b.

2. $_aX^b \xrightarrow{_{-}\beta^0} \xrightarrow{\alpha} {_CY^{215}} \xrightarrow{_{-}\beta^0} {_{110}Y^d}$ Find a, b, c and d.

3. $_{92}U^{238} \xrightarrow{n\alpha, n'\,_{-}\beta^0} {_{82}Pb^{206}}$. Find n & n'

4. Thorium isotope $_{90}Th^{232}$ emits some $\alpha$–particles and some $\beta$–particles and gets transformed into lead isotope $_{82}Pb^{200}$. Find the number of $\alpha$ and $\beta$ particles emitted.

5. A radioactive nucleus undergoes a series of decays according to the following scheme :

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta^-} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

If the mass number and atomic number of A are 180 and 72 respectively, what are these numbers for $A_4$?

6. Write nuclear reaction equations for

(i) $\alpha$-decay of $^{226}_{88}Ra$

(ii) $\alpha$-decay of $^{242}_{94}Pu$

(iii) $\beta^-$-decay of $^{32}_{15}P$

(iv) $\beta^-$-decay of $^{210}_{83}Bi$

(v) $\beta^+$-decay of $^{11}_{6}C$

(vi) $\beta^+$-decay of $^{97}_{43}Tc$

(vii) Electron capture of $^{120}_{54}Xe$

## 4. NUCLEAR REACTIONS

- It can be written as X (a, b) Y  i. e. $X + a \rightarrow Y + b$
- All nuclear reactions follow conservation of number of nucleons and charge (i.e.Z) conservation as well as energy + mass conservations, linear and angular momentum.

## 5. MATHEMATICAL DERIVATION OF EXPONENTIAL DECAY

**Rutherford and Soddy's law**

At an instant rate of decay of active nuclei is directly proportional to the number of active nuclei at that instant

$-\dfrac{dN}{dt}$ = rate of decay of nuclei at time t

N = active nuclei at time t and $-\dfrac{dN}{dt} \propto N$ or $-\dfrac{dN}{dt} = \lambda N$  ...(i)

Here $\lambda$ is the decay constant which depends only on the nature of substance.

equation (i) can be written as $\frac{dN}{N} = -\lambda\, dt$

Integrate it $\int \frac{dN}{N} = -\lambda \int dt$

$$\log_e N = -\lambda t + C \qquad \text{...(ii)}$$

Let at $t = 0$ number of active nuclei were $N_0$

(by putting $t = 0$ and $N = N_0$ in equation (ii) )

$$\log_e N_0 = C$$

Now equation (ii) is $\log_e N = -\lambda t + \log_e N_0$

$$\log_e N - \log_e N_0 = -\lambda t \quad \Rightarrow \quad \log_e \frac{N}{N_0} = -\lambda t \quad \text{i.e.} \quad \frac{N}{N_0} = e^{-\lambda t}$$

$$N = N_0 e^{-\lambda t} \qquad \text{...(iii)}$$

equation (iii) gives number of active nuclei in a sample at desire instant t.

## GOLDEN KEY POINTS

- Number of nuclei, which has been decayed in duration t $\Rightarrow N' = N_0 - N = N_0(1 - e^{-\lambda t})$
- $\lambda$ is independent of amount of active substance (N or m) and time and any physical or chemical changes.
- $\lambda$ is called decay constant or disintegration constant or radioactivity constant or Rutherford Soddy's constant or the probability of decay per unit time of a nucleus.

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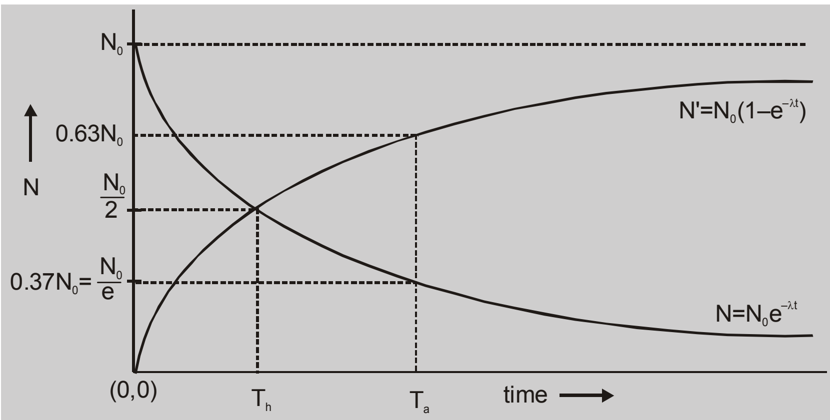
**Graph :** Time versus N (or N')




### 5.1 Half life ($T_h$)

It is the time during which number of active nuclei reduce to half of initial value.

If at $t = 0$ no. of active nuclei $N_0$ then at $t = T_h$ number of active nuclei will be $\frac{N_0}{2}$

from decay equation $N = N_0 e^{-\lambda t}$

$$\frac{N_0}{2} = N_0 e^{-\lambda T_h} \quad \Rightarrow \quad T_h = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda} \approx \frac{0.7}{\lambda}$$

## 5.2 Mean or Average Life ($T_a$)

It is the average of age of all active nuclei i.e.

$$T_a = \frac{\text{sum of times of existance of all nuclei in a sample}}{\text{initial number of active nuclei in that sample}} = \frac{1}{\lambda}$$

(i) At t = 0, number of active nuclei = $N_0$ then

number of active nuclei at $t = T_a$ is $N = N_0 e^{-\lambda T_a} = N_0 e^{-1} = \frac{N_0}{e} = 0.37 N_0 = 37\%$ of $N_0$

(ii) Number of nuclei which have been disintegrated within duration $T_a$ is

$N' = N_0 - N = N_0 - 0.37\,N_0 = 0.63\,N_0 = 63\%$ of $N_0$

(iii) $T_a = \frac{1}{\lambda} = \frac{T_h}{\ln 2} = \frac{T_h}{0.693} = 1.44\,T_h$

(iv) Within duration $T_h \Rightarrow 50\%$ of $N_0$ decayed and 50% of $N_0$ remains active

(v) Within duration $T_a \Rightarrow 63\%$ of $N_0$ decayed and 37% of $N_0$ remains active

## 5.3 Activity of a sample (A or R) (or decay rate)

(i) It is the rate of decay of a radioactive sample $R = -\frac{dN}{dt} = N\lambda$ or $R = R_0 e^{-\lambda t}$

(ii) Activity of a sample at any instant depends upon number of active nuclei at that instant.

$R \propto N$ (or active mass) , $R \propto m$

(iii) R also decreases exponentially w.r.t. time same as the number of active nuclei decreases.

(iv) R is not a constant with N, m and time while $\lambda$, $T_h$ and $T_a$ are constant

(v) At t = 0, R = $R_0$ then at $t = T_h$ $\Rightarrow$ $R = \frac{R_0}{2}$ and at $t = T_a$ $\Rightarrow$ $R = \frac{R_0}{e}$ or $0.37\,R_0$

(vi) Similarly active mass of radioactive sample decreases exponentially. $m = m_0 e^{-\lambda t}$

(vii) Activity of m gm active sample (molecular weight $M_w$) is $R = \lambda N = \frac{0.693}{T_h}\left[\frac{N_{AV}}{M_W}\right] m$

here $N_{AV}$ = Avogadro number = $6.023 \times 10^{23}$

**SI UNIT of R :** 1 becquerel (1 Bq)= 1 decay/sec

**Other Unit is curie :** 1 Ci = $3.70 \times 10^{10}$ decays/sec

## GOLDEN KEY POINTS

- In radioactive sample a radioactive substance (A) converts into rather stable substance (B), B converts into more stable substance (C). This process ends into stable element. $A \to B \to C \to D \to$ .......
  - Stability order $D > C > B > A$
  - Radioactivity order $A > B > C > D$
  - For stable element $\lambda = 0$
  - For stable element $T_h = \infty$
- At equilibrium, rate of production of B = rate of decay of B (and also for C,D, etc.)

  Therefore number of active nuclei of B becomes constant (or activity $N\lambda$ also becomes constant)

  At equilibrium radio activities of all daughter nuclides are equal i.e.

$$\text{at radioactive equilibrium} \rightarrow \begin{cases} R_1 = R_2 = R_3 = R_4 \ldots \\ N_1\lambda_1 = N_2\lambda_2 = N_3\lambda_3 \end{cases}$$

At equilibrium $N_2 = N_1 \dfrac{\lambda_1}{\lambda_2} = N_1 \dfrac{T_{h_2}}{T_{h_1}} = \dfrac{m_2}{M_{W_2}} N_A = \dfrac{m_1}{M_{W_1}} N_A \dfrac{T_{h_2}}{T_{h_1}} \quad \Rightarrow \quad m_2 = m_1 \left[\dfrac{M_{W_2}}{M_{W_1}}\right]\left[\dfrac{T_{h_2}}{T_{h_1}}\right]$

- Radiation dozes is measured in **sieverts** (Sv) or **Rontgen**.
- **Uses of radioactive isotopes in human life**

**(a) In medicine**

(i) Testing of blood circulation – $Cr^{57}$

(ii) Brain tumer detecting – $Hg^{203}$

(iii) Thyroid testing (cancer) – $I^{131}$

(iv) Cancer cure – $Co^{60}$

(v) Blood cancer cure – $Au^{189}$ /$Na^{24}$

**(b) In Archaeology**

(i) For determining age of archaeological sample ($\approx 30{,}000$ yr old) – $C^{14}$ (carbon dating)

(ii) For determining age of earth or meteorites (very old) – $K^{40}$ and Uranium

**(c) In Agriculture**

(i) For protacting potato from earthworm – $Co^{60}$

(ii) Artificial rains by – AgI

(iii) As fertilizers – $P^{32}$

- **Geiger – Muller counter** is used for detecting (or counting) the $\alpha$ particles and $\beta$–particles.

# Illustrations

**Illustration 3.**

In a old rock, ratio of nuclei of uranium and lead is 1 : 1. Half life of uranium is $4.5 \times 10^9$ yrs. Let initially it contains only uranium nuclei. How old is the rock ?

**Solution.**

Let present active nuclei of uranium is N then intial active nuclei is 2N.

Present active fraction of uranium $= \dfrac{1}{2} \Rightarrow \dfrac{1}{2} = \dfrac{1}{2^{t/T_{1/2}}}$

$$\text{or} \quad \frac{t}{T_{1/2}} = 1 \quad \text{or} \quad t = T_{1/2} = 4.5 \times 10^9 \text{yr}$$

**Illustration 4.**

The mean lives of a radioactive substance are $T_1$ and $T_2$ for $\alpha$–emission and $\beta$–emission respectively. If it is decaying by both $\alpha$–emission and $\beta$–emission simultaneously then find its mean life and decay constant ?

**Solution.**

$$\because \quad \lambda = \lambda_1 + \lambda_2 \quad \Rightarrow \quad \lambda = \frac{1}{T_1} + \frac{1}{T_2} \Rightarrow \quad \tau = \frac{T_1 T_2}{T_1 + T_2} \qquad [\because \tau = \frac{1}{\lambda}]$$

**Illustration 5.**

The half lives of X and Y are 3 minutes and 27 minutes respectively. At some instant activity of both are same, then the ratio of active nuclei of X and Y at that instant is ?

**Solution.**

$$A_1 = \lambda_1 N_1 \qquad \text{and} \qquad A_2 = \lambda_2 N_2$$

$$A_1 = A_2 \qquad \Rightarrow \qquad \frac{0.693}{T_1} N_1 = \frac{0.693}{T_2} N_2$$

$$\Rightarrow \quad \frac{N_1}{T_1} = \frac{N_2}{T_2} \qquad \Rightarrow \qquad \frac{N_1}{N_2} = \frac{3}{27} = \frac{1}{9} \qquad \Rightarrow \qquad N_1 : N_2 = 1 : 9$$

**Illustration 6.**

Decay constant of two radioactive samples is $\lambda$ and $3\lambda$ respectively. At $t = 0$, they have equal number of active nuclei. Calculate when will be the ratio of active nuclei becomes $e : 1$.

**Solution.**

Number of active nuclei of two radioactive sample is

$$N_1 = N_{01} e^{-\lambda t} \text{ and } N_2 = N_{02} e^{-3\lambda t} \qquad \therefore \quad \frac{N_1}{N_2} = \frac{e}{1} = \frac{N_{01} e^{-\lambda t}}{N_{02} e^{-3\lambda t}} = e^{2\lambda t} \qquad [\because \ N_{01} = N_{02}]$$

$$\therefore \quad 1 = 2\lambda t \qquad \Rightarrow \quad t = \frac{1}{2\lambda}$$

**Illustration 7.**

The fraction of a radioactive sample which remains active after time t is $\frac{9}{16}$. What fraction remains active after $\frac{t}{2}$ time.

**Solution.**

$$\text{Active fraction} = \frac{N}{N_0} = e^{-\lambda t} \qquad \text{At time t,} \quad \frac{9}{16} = e^{-\lambda t}$$

$$\text{At time } t/2 \text{ active fraction} = x = e^{-\lambda t/2} = \left(e^{-\lambda t}\right)^{\frac{1}{2}} \qquad \text{So } x = \left(\frac{9}{16}\right)^{\frac{1}{2}} = \frac{3}{4}$$

**Illustration 8.**

Calculate the radioactive disintegration constant if $3.7 \times 10^{10}$ alpha particles are emitted by 1 gram of radium per second. Avogadro's number is $6.03 \times 10^{23}$ and the mass number of radium is 226.

**Solution.**

$$\text{Activity} = N\lambda = \left(\frac{N_A}{M_w} \times m\right)\lambda \Rightarrow 3.7 \times 10^{10} = \left(\frac{6.03 \times 10^{23}}{226} \times 1\right)\lambda$$

$$\lambda = \frac{3.7 \times 10^{10} \times 226}{6.03 \times 10^{23}} = 1.38 \times 10^{-11} \text{ per second}$$

**Illustration 9.**

A free neutron is unstable against $\beta$–decay with a half life of about 600 seconds.–

(i) Write the expression of this decay process.

(ii) If there are 600 free neutrons initially, calculate the time by which 450 of them have decayed. Also determine the initial decay rate of the sample. **[AIPMT 2005]**

**Solution.**

(i) $n \rightarrow p + e^{-} + \bar{\nu}$

(ii) The number of undecayed neutron would be 150 by using $N = N_0e^{-\lambda t}$

$150 = 600e^{-\lambda t} \Rightarrow t = 2T_{1/2} = 1200$ sec

Decay rate (initial) $R = \lambda N_0 = 0.693$ Bq

**Illustration 10.**

Obtain the amount of polonium ($_{84}Po^{210}$) necessary to provide a radioactivity source of 5.0 mili curie strength. The half life of polonium is 138 days. (given : 1 curie = $3.7 \times 10^{10}$ disintregration/sec., Avogadro number = $6.02 \times 10^{26}$ per k-mole). **[AIPMT 2006]**

**Solution.**

$$\frac{dN}{dt} = -\lambda N \quad \Rightarrow \quad N = -\frac{1}{\lambda}\frac{dN}{dt}$$

Given : $\frac{dN}{dt} = 5 \times 10^{-3} \times 3.7 \times 10^{10}$ disint./sec. & $T_{1/2} = 138 \times 24 \times 3600$ sec.

$$\Rightarrow N = \frac{138 \times 24 \times 3600 \times 5 \times 3.7 \times 10^{7}}{0.693} = 3.18 \times 10^{15} \text{ atoms}$$

But mass of one $_{84}Po^{210}$ atoms $= \frac{210}{6.02 \times 10^{23}}$

Amount of $_{84}Po^{210}$ in grams required $= \frac{210 \times 3.18 \times 10^{15}}{6.02 \times 10^{23}} = 1.11 \times 10^{-6}$

## BEGINNER'S BOX-3

**1.** The half lives of radioactive elements x and y are 3 minute and 27 minute respectively. If the activities of both are same, then calculate the ratio of number of atoms of x and y.

**2.** Carbon has two stable isotopes. Natural carbon has 98.9% carbon–12 and 1.1% carbon–13, calculate the average atomic weight of carbon.

**3.** A radioactive isotope has a half life of T. After how much time is its activity reduced to 6.25% of its original activity ?

**4.** $\frac{2}{3}$ fraction of a sample disintegrates in 7 days. How much fraction of it will decay in 21 days ?

**5.** The half life of radium is 1600 years. After how many years 25% of radium block remains undecayed ?

**6.** A radioactive isotope has a half-life of T years. How long will it take the activity to reduce to a) 3.125%, b) 1% of its original value?

**7.** Obtain the amount of $^{60}_{27}Co$ necessary to provide a radioactive source of 8.0 mCi strength. The half-life of $^{60}_{27}Co$ is 5.3 years.

# ANSWERS

## BEGINNER'S BOX-1

**1.** (i) –4.031 MeV, endothermic

(ii) 5.64 MeV, exothermic

**2.** 278.92 MeV

**3.** $4.55 \times 10^4$ kWh.

**4.** $5 \times 10^{14}$

**5.** 10.5 g

**6.** $2.7 \times 10^{14}$ J

**7.** 1 : 1

## BEGINNER'S BOX-2

**1.** a = 89, b = 234

**2.** a = 110, b = 219, c = 109, d = 215

**3.** n = 8, n' = 6

**4.** $N_\alpha = 8$, $N_\beta = 8$

**5.** Mass number = 172 and Atomic number = 69

**6.** (i) $^{226}_{88}Ra \xrightarrow{-\alpha} {}^{222}_{86}Rn + {}^{4}_{2}He$

(ii) $^{242}_{94}Pu \xrightarrow{-\alpha} {}^{238}_{92}U + {}^{4}_{2}He$

(iii) $^{32}_{15}P \xrightarrow{-\beta^-} {}^{32}_{16}S + {}^{0}_{-1}\beta + \overline{\upsilon}$

(iv) $^{210}_{83}Bi \xrightarrow{-\beta^-} {}^{210}_{84}Po + {}^{0}_{-1}\beta + \overline{\upsilon}$

(v) $^{11}_{6}C \xrightarrow{-\beta^+} {}^{11}_{5}B + {}^{0}_{+1}\beta + \upsilon$

(vi) $^{97}_{43}Tc \xrightarrow{-\beta^+} {}^{97}_{42}Mo + {}^{0}_{+1}\beta + \upsilon$

(vii) $^{120}_{54}Xe + {}_{-1}e^0 \xrightarrow{\text{electron capture}} {}^{120}_{53}I + \text{X-Ray} + \upsilon$

## BEGINNER'S BOX-3

**1.** $\frac{1}{9}$

**2.** 12.011 amu

**3.** 4T

**4.** $\frac{26}{27}$

**5.** 3200 years

**6.** (a) 5T, (b) 6.64T

**7.** 7 μg

# APPENDIX

### Elementary particles

- Bosons (s = 0, ±1, ±2....)
  - Photon
  - Higgs boson (s = 0)
  - Gluons
  - W boson & Z boson
  - Graviton (Hypothetical)
  - π-mesons
- Fermions (s = ±1/2, ±3/2....)
  - Baryons → $n, \overline{n}, p, \overline{p}$ etc.
  - Leptons → $e, e^+, \nu, \overline{\nu}$ etc.
  - Quarks → up and down etc.

**Note :** Fermions obey pauli's exclusion principle but bosons do not obey it.

## EXERCISE-I (Conceptual Questions)

### NUCLEAR PHYSICS

**1.** Let $F_{pp}$, $F_{pn}$ and $F_{nn}$ denote the nuclear force between proton–proton, proton–neutron and neutron–neutron pair respectively. When separation is 1 fm :-

(1) $F_{pp} < F_{pn} = F_{nn}$  (2) $F_{pp} > F_{pn} = F_{nn}$

(3) $F_{pp} = F_{pn} = F_{nn}$  (4) $F_{pp} < F_{pn} < F_{nn}$

**2.** A nuclear fission is given below

$A^{240} \rightarrow B^{100} + C^{140} + Q(\text{energy})$

Let binding energy per nucleon of nucleus A, B and C is 7.6 MeV, 8.1 MeV and 8.1 MeV respectively. Value of Q is :-(Approximately)

(1) 20 MeV  (2) 220 MeV

(3) 120 MeV  (4) 240 MeV

**3.** How much energy will be released when 10 kg of $U^{235}$ is completely converts into energy :-

(1) $5 \times 10^{27}$ MeV  (2) $5 \times 10^{24}$ MeV

(3) $9 \times 10^{17}$ J  (4) All of these

**4.** How much energy is released when 2 mole of $U^{235}$ is fissioned :-

(1) $10^{24}$ MeV  (2) $24 \times 10^{25}$ MeV

(3) $10^{24}$ J  (4) $10^{24}$ kWh

**5.** As the mass number increases, binding energy per nucleon :-

(1) increases

(2) decreases

(3) remains same

(4) may increase or may decrease

**6.** Possible forces on a proton by a proton in a nucleus is/are :-

(1) Coulomb force  (2) Nuclear force

(3) Gravitational force  (4) All of these

**7.** The energy radiated by a red giant star produces by :-

(1) Fission process

(2) Fusion process

(3) Chemical burning of hydrogen

(4) Gravitational contraction

**8.** In the process of atomic explosion, the most of fission energy is released in the form of :–

(1) $\gamma$ - rays

(2) Kinetic energy of products

(3) Infra red rays

(4) Visible light

**9.** Which of the following nucleus is fissionable by slow neutrons :-

(1) $_{92}U^{238}$  (2) $_{93}Np^{239}$

(3) $_{92}U^{235}$  (4) $_{2}He^{4}$

**10.** The example of nuclear fusion is .

(1) formation of barium and krypton from uranium

(2) formation of helium from hydrogen

(3) formation of plutonium –235 from uranium –235

(4) formation of water from hydrogen and oxygen

**11.** Electron - positron pair can be created by $\gamma$ - rays. In this process the minimum energy of $\gamma$ -rays should be :-

(1) 5.0 MeV  (2) 4.02 MeV

(3) 15.0 MeV  (4) 1.02 MeV

**12.** For nuclear reaction :

$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{144} + \ldots\ldots\ldots + 3\,{}_{0}n^{1}$

(1) $_{26}Kr^{89}$  (2) $_{36}Kr^{89}$

(3) $_{26}Sr^{90}$  (4) $_{38}Sr^{89}$

**13.** For the given reaction, the particle X is -

$_6C^{11} \rightarrow {}_5B^{11} + \beta^+ + X$

(1) Neutron (2) Anti neutrino

(3) Neutrino (4) Proton

**14.** In a breeder reactor, useful fuel obtained from $U^{238}$ is :

(1) $Ac^{233}$ (2) $Th^{238}$

(3) $U^{235}$ (4) $Pu^{239}$

**15.** Boron used in Atomic Reactor for:-

(1) absorbption of neutrons

(2) absorbption of $\alpha$ - particles

(3) speed up the reaction

(4) change the reaction

**16.** Who discovered the nuclear fission :-

(1) Otto Hahn and strassman

(2) Fermi

(3) Baithe

(4) Rutherford

**17.** Which one is best neutron moderator in all respects:

(1) Barium oxide (2) Water

(3) Graphite (4) Heavy water

**18.** X(n, $\alpha$) ${}^{7}_{3}\text{Li}$ , then the element X will be :–

(1) ${}^{10}_{5}\text{B}$ (2) ${}^{9}_{5}\text{B}$

(3) ${}^{11}_{4}\text{Be}$ (4) ${}^{4}_{2}\text{He}$

**19.** $M_n$ and $M_p$ represent the mass of neutron and proton respectively. An element having nuclear mass M has N neutrons and Z-protons, then the correct relation will be :-

(1) $M<\{N.M_n+Z.M_p\}$ (2) $M>\{N.M_n+Z.M_p\}$

(3) $M=\{N.M_n+Z.M_p\}$ (4) $M=N\{M_n + M_p\}$

**20.** Energy is released in nuclear fission is due to

(a) Few mass is converted into energy

(b) Total binding energy of fragments is more than the B.E. of parental element

(c) Total B.E. of fragments is less than the B.E. of parental element

(d) Total B.E. of fragments is equals to the B.E. of parental element is

(1) a,c (2) a,b (3) a,d (4) All

**21.** Energy in an atom bomb is produced by the process of :

(1) nuclear fusion

(2) nuclear fission

(3) combination of hydrogen atoms

(4) combination of electrons and protons

**22.** Assuming that 200 MeV of energy is released per fission of $_{92}U^{235}$ atom. Find the number of fission per second required to release 1 kW power :-

(1) $3.125 \times 10^{13}$ (2) $3.125 \times 10^{14}$

(3) $3.125 \times 10^{15}$ (4) $3.125 \times 10^{16}$

**23.** 1 a.m.u. ($1.66 \times 10^{-27}$ kg) is equal to

(1) 139 MeV/$c^2$ (2) 39 MeV/$c^2$

(3) 93 MeV/$c^2$ (4) 931 MeV/$c^2$

**24.** In nuclear fission the percentage of mass converted into energy is about :-

(1) 0.1% (2) 1% (3) 10% (4) 0.01%

**25.** Which of the following are suitable for the fusion process :-

(1) Light nuclei

(2) heavy nuclei

(3) Element must be lying in the middle of the periodic table

(4) Middle elements, which are lying on binding energy curve

**26.** Which one of the following particle is unstable ?

(1) $\alpha$-particle (2) electron

(3) proton (4) neutron

**27.** Which of the following is weakest force :-

(1) Gravitational force (2) Electric force

(3) Magnetic force (4) Nuclear force

**28.** The volume occupied by an atom is greater than the volume of the nucleus by a factor of about :-

(1) $10^1$ (2) $10^5$

(3) $10^{10}$ (4) $10^{15}$

**29.** The mass of proton is 1.0073 u and that of neutron is 1.0087 u ( u = atomic mass unit). The binding energy of ${}_2^4He$ is :-

(1) 0.0305 J (2) 0.0305 erg

(3) 28.4 MeV (4) 0.061 u

(Given:- mass of helium nucleus $\approx 4.0015$ u)

**30.** The mass number of a nucleus is

(1) always less than its atomic number

(2) always more than its atomic number

(3) may equal to its atomic number

(4) sometimes less than and sometimes more than its atomic number

**31.** In the following reaction X is :–

${}_{20}Ca^{40} + X \rightarrow {}_{21}Sc^{43} + {}_1H^1$

(1) Electron (2) Positron

(3) alpha particle (4) Proton

**32.** Nuclear fusion is possible :–

(1) only between light nuclei.

(2) only between heavy nuclei.

(3) between both light and heavy nuclei.

(4) only between nuclei which are stable against $\beta$–decay.

**33.** The order of nuclear density is

(1) $10^{13}$ kg/m$^3$ (2) $10^{15}$ kg/m$^3$

(3) $10^{17}$ kg/m$^3$ (4) $10^{19}$ kg/m$^3$

**34.** Two light nuclei of masses $m_1$ and $m_2$ are fused to form a more stable nucleus of mass $m_3$ then :-

(1) $m_3 = |m_1 - m_2|$ (2) $m_3 < (m_1 + m_2)$

(3) $m_3 > (m_1 + m_2)$ (4) $m_3 = m_1 + m_2$

**35.** A nucleus represented by the symbol ${}_Z^AX$ has :-

(1) Z protons and A – Z neutrons

(2) Z protons and A neutrons

(3) A protons and Z – A neutrons

(4) Z neutrons and A – Z protons

**36.** $M_p$ denotes the mass of a proton and $M_n$ that of a neutron. A given nucleus, of binding energy B, contains Z protons and N neutrons. The mass M (N, Z) of the nucleus is given by (c is velocity of light) :-

(1) $M(N, Z) = NM_n + ZM_p + Bc^2$

(2) $M(N, Z) = NM_n + ZM_p - B/c^2$

(3) $M(N, Z) = NM_n + ZM_p + B/c^2$

(4) $M(N, Z) = NM_n + ZM_p - Bc^2$

**37.** Mass equivalent to energy 931 MeV is

(1) $6.02 \times 10^{-27}$ kg (2) $1.66 \times 10^{-27}$ kg

(3) $16.66 \times 10^{-26}$ kg (4) $6.02 \times 10^{-26}$ kg

**38.** One milligram of matter converted into energy will give

(1) 9 J (2) $9 \times 10^{13}$ J

(3) $9 \times 10^5$ J (4) $9 \times 10^{10}$ J

**39.** Force acting on proton-proton inside a nucleus is–

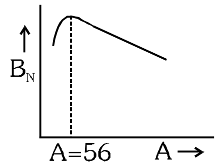
(1) Nuclear force > electric force

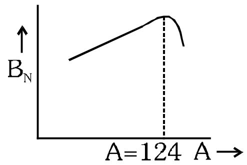
(2) Electric force > Nuclear force

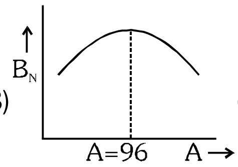
(3) Gravitational force > Nuclear force

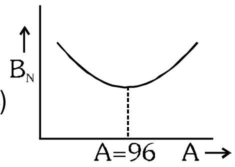
(4) None of the above

**40.** The dependence of binding energy per nucleon ($B_N$) on the mass number (A), is represented by

(1) 


(2) 


(3) 


(4) 


**41.** Which one of the following pairs of nuclei are isotones :-

(1) ${}_{34}Se^{74}$, ${}_{31}Ga^{71}$ (2) ${}_{38}Sr^{84}$, ${}_{38}Sr^{86}$

(3) ${}_{42}Mo^{92}$, ${}_{40}Zr^{92}$ (4) ${}_{20}Ca^{40}$, ${}_{16}S^{32}$

**42.** Which one of the following is a possible nuclear reaction :-

(1) ${}^{10}_{5}B + {}^{4}_{2}He \longrightarrow {}^{13}_{7}N + {}^{1}_{1}H$

(2) ${}^{23}_{11}Na + {}^{1}_{1}H \longrightarrow {}^{22}_{10}Ne + {}^{4}_{2}He$

(3) ${}^{239}_{93}Np \longrightarrow {}^{239}_{94}Pu + \beta^{-} + \overline{\nu}$

(4) ${}^{11}_{7}N + {}^{1}_{1}H \longrightarrow {}^{12}_{6}C + \beta^{-} + \nu$

**43.** In the reaction ${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n$ . If the binding energies of ${}^{2}_{1}H$, ${}^{3}_{1}H$ and ${}^{4}_{2}He$ are respectively a, b and c (in MeV), then the energy (in MeV) released in this reaction is

(1) a + b + c (2) c + a – b

(3) c – a – b (4) a + b + c

**44.** In any fission process the ratio $\dfrac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is –

(1) Greater than 1

(2) Depends on the mass of the parent nucleus

(3) Equal to 1

(4) Less than 1

**45.** Fission of nuclei is possible because the binding energy per nucleon in them –

(1) Decreases with mass number at low mass numbers.

(2) Increases with mass number at low mass numbers.

(3) Decreases with mass number at high mass numbers.

(4) Increases with mass number at high mass numbers.

**46.** The main function of moderators in nuclear reactors is to :-

(1) decrease the energy of neutrons

(2) absorb the extra neutrons

(3) provide shield from nuclear radiations

(4) provide cooling

## RADIOACTIVITY

**47.** Probability of survival of a radioactive nucleus in one mean life is :-

(1) $\frac{1}{2}$ (2) $\frac{1}{e}$ (3) $\frac{1}{4}$ (4) $\frac{1}{5}$

**48.** Ratio of initial active nuclei in two different samples is 2 : 3. Their half lives are one hour and two hours respectively. Ratio of active nuclei at the end of 6 hours will be :-

(1) 1 : 1 (2) 1 : 12 (3) 4 : 3 (4) 3 : 4

**49.** Atomic weight of a radioactive element is $M_w$ gram. Radioactivity of m gram. of its mass is :–

($N_A$ = Avogadro number, $\lambda$ = decay constant)

(1) $N_A \lambda$ (2) $\left(\frac{N_A}{M_w} m\right)\lambda$

(3) $\left(\frac{N_A}{m}\right)\lambda$ (4) $\left(\frac{N_A}{m} M_w\right)\lambda$

**50.** Which spectrum is continuous

(1) α–rays (2) β–rays

(3) γ–rays (4) All of these

**51.** Which statement about radioactive radiations is true

(1) Speed of $\alpha$-particles is a characteristic property.

(2) Speed of $\beta$-particles is a characteristic property.

(3) Speed of $\gamma$-photon is a characteristic property.

(4) All of these.

**52.** Which one moves with greatest speed :-

(1) $\alpha$-rays (2) $\beta$–rays

(3) $\gamma$–rays (4) cathode rays

**53.** For a radioactive sample, at given instant, number of active nuclei is N and its decay constant is $\lambda$ then the incorrect relation is–

(1) $N\lambda$ = activity at given instant.

(2) $\lambda$ = decay probability per unit time for a nucleus

(3) After the next $\frac{1}{\lambda}$ time interval, active nuclei in the sample will be $N\left(1-\frac{1}{e}\right)$

(4) The half life of the sample = $\frac{\ell n2}{\lambda}$

**54.** If a nucleus is emitting $e^-$ particle, its neutron to proton ratio (n/p) will :–

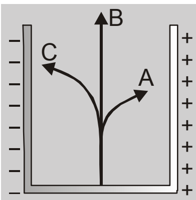
(1) Increase.

(2) Decrease

(3) Remain unchanged

(4) Can't be determind.

**55.** A radioactive source is kept in an uniform electric field $\alpha$, $\beta$ and $\gamma$- particle are emitting. $\alpha,\beta,\gamma$ are respectively :-




(1) A,B,C

(2) A,C,B

(3) C,A,B

(4) C,B,A

**56.** The rate of disintegration of a radioactive sample can be increased by :-

(1) Increasing the temperature

(2) Increasing the pressure

(3) Chemical reaction

(4) It is not possibe

**57.** In a radioactive decay, neither the atomic number nor the mass number changes. Which of the following would be emitted in the decay process.

(1) Proton (2) Neutron

(3) Electron (4) Photon

**58.** At some instant two radioactive substance are having amount in ratio of 2 : 1. Their half lives are 12 hrs and 16 hrs then after two days the ratio of their quantities is

(1) 1 : 1 (2) 2 : 1 (3) 1 : 2 (4) 1 : 4

**59.** The isotope used for curing the cancer is :

(1) K (40) (2) Co (60)

(3) Sr (90) (4) I (131)

**60.** 'Rn' decays into 'Po' by emitting $\alpha$ - particle with half life of 4 days. A sample contains $6.4 \times 10^{10}$ atoms of Rn. After 12 days, the number of atoms of 'Rn' left in the sample will be-

(1) $3.2 \times 10^{10}$ (2) $0.53 \times 10^{10}$

(3) $2.1 \times 10^{10}$ (4) $0.8 \times 10^{10}$

**61.** Neutrino is a particle, which is :

(1) charged like an electron and has no spin

(2) chargeless and has spin

(3) chargeless and has no spin

(4) charged like an electron and has spin

**62.** A radioactive element ${}_{90}X^{238}$ decays in to ${}_{83}Y^{222}$. The number of $\beta$ - particles emitted is :

(1) 2 (2) 4 (3) 6 (4) 1

**63.** The relation between $\lambda$ and $T_{1/2}$ as :- ($T_{1/2} \rightarrow$ half life, $\lambda \rightarrow$ decay constant)

(1) $T_{1/2} = \dfrac{\ell n2}{\lambda}$ (2) $T_{1/2}\ \ell n2 = \lambda$

(3) $T_{1/2} = \dfrac{1}{\lambda}$ (4) $(\lambda + T_{1/2}) = \dfrac{\ell n2}{2}$

**64.** The half life of a radioactive material is 5 years. The probability of disintegration for a nucleus in 10 years is :-

(1) 0.50 (2) 0.25 (3) 0.60 (4) 0.75

**65.** 10.24 g radioactive substance has half life 3.8 days. After 19 days, its remaining quantity is :-

(1) 0.151 g (2) 0.32 g (3) 1.51 g (4) 0.16 g

**66.** A radioactive reaction is ${}_{92}U^{238} \rightarrow {}_{82}Pb^{206}$ . How many $\alpha$ and $\beta$ particles are emitted ?

(1) $10\alpha$, $6\beta$ (2) 4 proton, 8 neutron

(3) 6 electron, 8 proton (4) $6\beta$, $8\alpha$

**67.** Which rays contain (+ Ve) charged particle:–

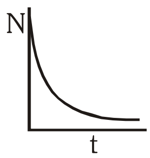
(1) $\alpha$–rays (2) $\beta$–rays (3) $\gamma$–rays (4) X–rays

**68.** Half life of radioactive element is 12.5 Hour and its quantity is 256 gram. After how much time its quantity will remain 1 gram :–

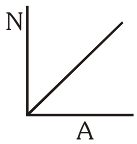
(1) 50 Hrs (2) 100 Hrs

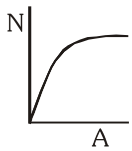
(3) 150 Hrs (4) 200 Hrs

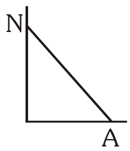
**69.** The number of undecayed nuclei N in a sample of radioactive material as a function of time is shown in the graph

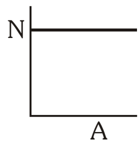



Which of the following graph correctly shows the relationship between N and the activity A ?

(1)



(2)



(3)



(4)



**70.** A sample of radioactive element containing $4 \times 10^{16}$ active nuclei. Half life of element is 10 days, then number of decayed nuclei after 30 days :-

(1) $0.5 \times 10^{16}$ (2) $2 \times 10^{16}$

(3) $3.5 \times 10^{16}$ (4) $1 \times 10^{16}$

**71.** When ${}_{90}Th^{238}$ changes into ${}_{83}Bi^{222}$, then the number of emitted $\alpha$ and $\beta$-particles are :-

(1) $8\alpha$, $7\beta$ (2) $4\alpha$, $7\beta$

(3) $4\alpha$, $4\beta$ (4) $4\alpha$, $1\beta$

**72.** A radioactive nucleus decay as follows :-

$$X \xrightarrow{\alpha} X_1 \xrightarrow{\beta} X_2 \xrightarrow{\alpha} X_3 \xrightarrow{\gamma} X_4,$$

if the atomic number and the mass number of X are 72 and 180 then the mass number and atomic number of $X_4$ are :-

(1) 172, 70 (2) 171,69

(3) 172, 69 (4) 172, 68

**73.** The decay constant of a radioactive sample is $\lambda$ . The respective values of its half life and meanlife are :-

(1) $\dfrac{1}{\lambda}$ and $(\log_e 2)$ (2) $\dfrac{\log_e 2}{\lambda}$ and $\dfrac{1}{\lambda}$

(3) $\lambda\ (\log_e 2)$ and $\dfrac{1}{\lambda}$ (4) $\dfrac{2}{\lambda}$ and $\dfrac{1}{\lambda}$

**74.** In a mean life of a radioactive sample :-

(1) About 1/3 of substance disintegrate

(2) About 2/3 of substance disintegrate

(3) About 90% of the substance disintegrate

(4) Almost all the substance disintegrates

**75.** Activity of a radioactive element is $10^3$ dps. Its half life is 1 second. After 3 seconds, its activity will be (dps = decay per second) :-

(1) 1000 dps (2) 250 dps

(3) 125 dps (4) None of these

**76.** A sample of radioactive element has a mass of 10 gram at an instant t = 0. The approximate mass of this element in the sample after two mean lives is :-

(1) 1.35 gram (2) 2.50 gram

(3) 3.70 gram (4) 6.30 gram

**77.** Which of the following ray are **not** electromagnetic waves :-

(1) X-rays (2) $\gamma$-rays

(3) $\beta$-rays (4) Heat rays

**78.** A radioactive substance decays to $1/16^{th}$ of its initial activity in 40 days. The half–life of the radioactive substance expressed in days is :–

(1) 2.5 (2) 5 (3) 10 (4) 20

**79.** A nuclear reaction given by

${}_{Z}X^{A} \rightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0} + \bar{\nu}$ represents

(1) $\beta$-decay (2) $\gamma$-decay (3) fusion (4) fission

**80.** If half-life of a radioactive substance is 60 minutes, then the percentage decay in 4 hours is :

(1) 50% (2) 71% (3) 85% (4) 93.7%

**81.** The active amount of radioactive substance left after one hour whose half life is 20 minutes is :

(1) $\frac{1}{8}$ (2) $\frac{1}{32}$ (3) $\frac{1}{16}$ (4) $\frac{1}{9}$

**82.** Initial decay rate of a substance is 800 disintegration/sec. If half life of substance is 1 sec. then after three second the decay rate will be :–

(1) 800 disintegration/sec.

(2) 400 disintegration/sec.

(3) 200 disintegration/sec.

(4) 100 disintegration/sec.

**83.** Plutonium - decays with a half life of 24000 years. If plutonium is stored for 72000 years, then the fraction of plutonium that remains, is

(1) 1/8 (2) 1/4 (3) 1/3 (4) 1/2

**84.** Which of the following radiations gets deflected by a magnetic field ?

(1) X-rays (2) $\gamma$-rays

(3) $\beta$-rays (4) radio waves

**85.** Fraction of tritium left after 125 years (half life of tritium is 12.5 years) is

(1) 1/1024 (2) 1/2048

(3) 1/4096 (4) 1/8192

**86.** $\alpha$–Particles can be detected using :–

(1) Thin aluminium sheet (2) Barium sulphate

(3) Zinc sulphide screen (4) Gold foil

**87.** If half life period of radium is 1600 years then its average life is (approx) –

(1) 4200 years (2) 3530 years

(3) 2300 years (4) 2800 years

## EXERCISE-I (Conceptual Questions)

| Que. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ans.** | **3** | **3** | **3** | **2** | **4** | **4** | **2** | **2** | **3** | **2** | **4** | **2** | **3** | **4** | **1** |
| **Que.** | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
| **Ans.** | **1** | **4** | **1** | **1** | **2** | **2** | **1** | **4** | **1** | **1** | **4** | **1** | **4** | **3** | **3** |
| **Que.** | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
| **Ans.** | **3** | **1** | **3** | **2** | **1** | **2** | **2** | **4** | **1** | **1** | **1** | **3** | **3** | **4** | **3** |
| **Que.** | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| **Ans.** | **1** | **2** | **2** | **2** | **2** | **1** | **3** | **3** | **2** | **3** | **4** | **4** | **1** | **2** | **4** |
| **Que.** | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 |
| **Ans.** | **2** | **4** | **1** | **4** | **2** | **4** | **1** | **2** | **1** | **3** | **4** | **3** | **2** | **2** | **3** |
| **Que.** | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | | | |
| **Ans.** | **1** | **3** | **3** | **1** | **4** | **1** | **4** | **1** | **3** | **1** | **3** | **3** | | | |

## EXERCISE-II (Assertion & Reason)

### Directions for Assertion & Reason questions

These questions consist of two statements each, printed as Assertion and Reason. While answering these Questions you are required to choose any one of the following four responses.

**(A)** If both Assertion & Reason are True & the Reason is a correct explanation of the Assertion.

**(B)** If both Assertion & Reason are True but Reason is not a correct explanation of the Assertion.

**(C)** If Assertion is True but the Reason is False.

**(D)** If both Assertion & Reason are false.

**1.** ***Assertion :-*** Neutrons penetrate matter more readily as compared to protons. **[AIIMS-2003]**

***Reason :-*** Neutrons slightly more massive than protons.

(1) A (2) B (3) C (4) D

**2.** ***Assertion :–*** Nuclear binding energy per nucleon is in the order $^{9}_{4}Be > ^{7}_{3}Li > ^{4}_{2}He$

***Reason :–*** Binding energy per nuclear increases linearly with difference in number of neutrons and protons. **[AIIMS-2004]**

(1) A (2) B (3) C (4) D

**3.** ***Assertion :–*** Energy is released in nuclear fission.

***Reason :–*** Total binding energy of the fission fragments is larger than the total binding energy of the parent nucleus. **[AIIMS-2004]**

(1) A (2) B (3) C (4) D

**4.** ***Assertion :–*** Heavy water is preferred over ordinary water as a moderator in reactors.

***Reason :–*** Heavy water, used for slowing down the neutrons; has lesser absorption probability of neutrons than ordinary water. **[AIIMS 2004]**

(1) A (2) B (3) C (4) D

**5.** ***Assertion :–*** It is not possible to use $^{35}Cl$ as the fuel for fusion energy. **[AIIMS-2005]**

***Reason :–*** The binding energy of $^{35}Cl$ is too small.

(1) A (2) B (3) C (4) D

**6.** ***Assertion:–*** The binding energy per nucleon, for nuclei with atomic mass number A>100, decreases with A. **[AIIMS-2006]**

***Reason:–*** The nuclear forces are weak for heavier nuclei.

(1) A (2) B (3) C (4) D

**7.** ***Assertion :-*** Deuterium is a good moderator of fast neutrons. **[AIIMS 2013]**

***Reason :-*** Fast neutrons transfer about 90% of their kinetic energy to the nuclei of the moderator which is an inelastic collision.

(1) A (2) B (3) C (4) D

**8.** ***Assertion :-*** Beryllium, can be used as a moderator in nuclear fission reactor.

***Reason :-*** A fast moving electron on collision with a light stationary particle loses most of its energy in reactor . **[AIIMS-2015]**

(1) A (2) B (3) C (4) D

**9.** ***Assertion :-*** Water is used as coolant in radiators.

***Reason :-*** Because water has high specific heat capacity. **[AIIMS-2015]**

(1) A (2) B (3) C (4) D

**10.** ***Assertion :-*** A heavy nucleus may also undergo fission to give two fission fragments.

***Reason :-*** A heavy nucleus has a smaller coulomb force. **[AIIMS-2015]**

(1) A (2) B (3) C (4) D

**11.** ***Assertion :-*** Speed of radioactive $\alpha$–rays is a characteristic property.

***Reason :-*** Speed of $\alpha$–rays depends upon the kind of the nucleus.

(1) A (2) B (3) C (4) D

**12.** ***Assertion :-*** Nucleus may emit negative charged particles.

***Reason :-*** Nucleus contains negative charge also.

(1) A (2) B (3) C (4) D

13. ***Assertion :-*** $^{22}_{11}Na$ emits a positron giving $^{22}_{12}Mg$.

***Reason :-*** In $\beta^+$ emission neutron is transformed into proton. **[AIIMS-2003]**

(1) A (2) B (3) C (4) D

14. ***Assertion :-*** Radioactive nuclei emit $\beta^-$ particles.

***Reason :-*** Electrons exist inside the nucleus. **[AIIMS 2003]**

(1) A (2) B (3) C (4) D

15. ***Assertion:–*** Cobalt-60 is useful in cancer therapy.

***Reason:–*** Cobalt-60 is source of $\gamma$-radiations capable of killing cancerous cell. **[AIIMS 2006]**

(1) A (2) B (3) C (4) D

16. ***Assertion :-*** Co–60 is a source of gamma radiation.

***Reason :-*** Gamma emission is due to nuclear decay. **[AIIMS 2013]**

(1) A (2) B (3) C (4) D

17. ***Assertion :-*** Free proton doesn't undergo decay.

***Reason :-*** It violates the law of conservation of energy and Momentum. **[AIIMS 2016]**

(1) A (2) B (3) C (4) D

18. ***Assertion :-*** During $\beta$ decay, spectrum is continuous.

***Reason :-*** $\beta$ decay is spontaneous statistical process. **[AIIMS 2016]**

(1) A (2) B (3) C (4) D

19. ***Assertion :-*** Heavy nuclei are highly unstable.

***Reason :-*** In heavy nuclei, neutrons are much greater than protons. **[AIIMS 2016]**

(1) A (2) B (3) C (4) D

20. ***Assertion :-*** Nuclear force is short range while gravitation and electric force are universal.

***Reason :-*** Nuclear force does not follow inverse square law. **[AIIMS 2016]**

(1) A (2) B (3) C (4) D

21. ***Assertion :-*** $_{92}U^{238}$ gives spontaneous $\alpha$-decay.

***Reason :-*** Number of neutrons is significantly more than number of protons in $_{92}U^{238}$.

**[AIIMS 2017]**

(1) A (2) B (3) C (4) D

22. ***Assertion :-*** Nuclear energy is stored in nucleus among neucleons. **[AIIMS 2017]**

***Reason :-*** Protons and neutrons have potential energy due to strong interaction force.

(1) A (2) B (3) C (4) D

23. ***Assertion :-*** Energy released in fusion of $^{2}_{1}H$ and $^{3}_{1}H$ is lower compared to the fission of $^{235}U$ by slow neutrons. **[AIIMS 2018]**

***Reason :-*** $^{2}_{1}H$ and $^{3}_{1}H$ are lighter elements.

(1) A (2) B (3) C (4) D

24. ***Assertion :-*** A commercial nuclear power plant, under any condition, can not explode internally with the force of a nuclear bomb.

***Reason :-*** In a commercial nuclear reactor, fuel enrichment is kept low. **[AIIMS 2018]**

(1) A (2) B (3) C (4) D

25. ***Assertion :-*** $^{2}_{1}H$ and $^{3}_{1}H$ are more feasible for fusion process.

***Reason :-*** Binding energy per nucleon of $^{2}_{1}H$ and $^{3}_{1}H$ is very low. **[AIIMS 2018]**

(1) A (2) B (3) C (4) D

## EXERCISE-II (Assertion & Reason)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Que.** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **Ans.** | **2** | **4** | **1** | **1** | **3** | **3** | **3** | **3** | **1** | **3** | **1** | **3** | **4** | **3** | **1** |
| **Que.** | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | | | | | |
| **Ans.** | **1** | **1** | **2** | **2** | **2** | **2** | **1** | **2** | **1** | **1** | | | | | |